PLATINUM: THE MOST PRECIOUS OF THE METALS.[1]

BY

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WHEN I received the invitation to contribute a lecture to this season's programme of the Chemical and Physical Section, my thoughts, by reason of several circumstances, were so engrossed with the subject of platinum that I somewhat rashly promised to give a lecture on this in no sense novel theme.

Under the stress of other duties, I had almost forgotten my promise, when, about a month ago, I was informed that this evening had been assigned to me, and I was thus aroused to give some serious consideration to the task I had undertaken. Platinum! Of all subjects, why had I selected *it?* What new and interesting advances in our knowledge of the metal would justify my discussing it before an audience such as this?

On further reflection, however, it occurred to me that several reasons might be advanced in favor of my selection. In the first place, platinum, by virtue of many new applications in the arts, had become a subject of popular interest; secondly, that chemists, though constantly handling utensils made of the metal, are only in exceptional cases obliged to acquaint themselves with the special literature of the subject; and, thirdly, that the platinum group of metals, being almost invariably relegated to the last place in systematic courses in inorganic chemistry, is generally very briefly dismissed or not even reached in the lectures on this branch of chemistry.

In my own case platinum and the allied metals came into my range of interest very early in my scientific career, but for a number of years my interest in them had remained dormant until, some time ago, it was reawakened—first, by some assays and experiments which I made for a client, and again, in a rather unpleasant way, by an occurrence in the laboratory of the Central High School.

[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, April 11, 1912.

As you know, platinum vessels are extensively used in chemical experimentation and analysis. They constitute the most expensive part of the equipment in the chemist's workshop. As most of them are of small size, you will readily understand that in a laboratory to which many and all kinds of people have access the safe keeping of the platinum-ware not only necessitates special precautions, but also causes some anxiety now and then to those charged with it. Thus, in spite of the most explicit instructions, it will happen that a novice puts a platinum crucible out of commission while the instructor turns his back to him; and a fifty-dollar platinum dish may disappear from a desk as if it were made of the most volatile of substances.

I have been accustomed to handle and take charge of platinum apparatus of many descriptions and considerable value for a period of over thirty years. I had it impressed upon me with the first crucible I bought as a student that platinum must be treated with proper respect, and I have been fortunate in so far as I have never ruined a piece of platinum myself. There have been a few instances in which crucibles were damaged by students working under my direction, but until recently no theft of platinum had occurred in our laboratory, except, about a year ago, that of a small dish. Last fall, however, we had an experience which taught me that in addition to constant vigilance there is another precaution one cannot afford to neglect in taking care of the platinum stock of a large laboratory, and that is to keep it in a burglar-proof safe.

What happened then was briefly this. Returning to the school after an absence of several days, I opened the drawer in which I kept the platinum for general use in the laboratory, and discovered, to my amazement, that two of the largest dishes, worth at least $250, were missing. Otherwise the contents of the drawer, which contained many other platinum utensils, had not been disturbed, and the lock was perfectly intact. As the laboratory doors are always locked during the absence of the instructors, and only a few trusted employees of the school have access to these rooms, I was at a loss to account for the theft. I immediately reported the loss to my superiors, and with their approval, took what I considered the proper steps to recover the stolen articles. I furnished a description of the latter to all the principal dealers of platinum goods, and called on the Chief of the city's Detective Bureau, who promptly detailed one of his best men on the case, and also had my description of the dishes printed and sent out to the "old gold" and pawnbroker shops in the city. Three days later the detective called me up on the telephone and informed me that the "cups" had been found, and that I should call for them at the City Hall. You can imagine how relieved I felt when the precious pieces were safe and sound in my hands once more, and without any expense for their recovery.

Just how the theft was committed is still a mystery. The dishes had been offered to a local dealer in "old gold," who at once suspected that they had been obtained in some dishonest way, and had cleverly managed to get possession of them without directly paying the money asked by the thief and his accomplice. On receiving the notice he turned the articles over to the Detective Bureau without asking for any reward. The description of the person who offered the platinum for sale, together with other evidence found later, leaves little doubt as to who the thief was, but an unfortunate combination of circumstances frustrated his identification.

My reason for prefacing my lecture with this incident is twofold: it shows that we cannot be too careful in providing a safe place for the keeping of our platinum-ware, and it may afford some useful hints as to what course to pursue in the event of a theft.

Let us now take up our subject in a methodical way, and begin in the good old-fashioned manner with an historical sketch.

Unlike most of the useful metals, platinum remained unknown until comparatively recent times. Probably the earliest authentic reference to it is to be found in a work of Antonio de Ulloa, a Spanish naval officer, published in 1748, and entitled "A Narrative of a Journey to South America." In this Ulloa mentions it under the name of platina as a mineral which occurs in the Choco District of Colombia, and which is found admixed to the gold of that district. He describes it as an extremely tough substance that renders gold unworkable, as it cannot be extracted or removed by any of the ordinary processes.

Specimens of platinum, probably from the same source, were brought to England as early as 1735 by Charles Wood, who obtained them at Cartagena, in Colombia. William Brownrigg, who received some of this material from Wood in 1741, and published a description of it as a metalloid in 1750 (two years later than Ulloa), is now generally credited with the discovery of platinum. For many years it was erroneously ascribed to William Watson.

A more complete investigation of platinum was made by Scheffer, assayer of the Stockholm Mint, and the results were communicated to the Royal Academy of Stockholm in 1752. His material came from the gold-bearing sands of the river Pinto, in Colombia, and he called the new substance "white gold, or the seventh metal, known in Spain as *platina del Pinto*." Scheffer showed that platinum is a true metal, insoluble in nitric acid, but soluble in aqua regia; also, that it is infusible at the highest temperatures attainable in furnaces, but capable of forming fusible alloys with other metals and with arsenic.

Fairly pure platinum was first obtained by the German chemist Margraf, who made the important discovery that solutions of platinum chloride are precipitated by potassium and ammonium salts, but not by sodium salts. He also was the first to prepare spongy platinum. In 1778 the Count von Sickingen communicated to the French Academy the results of his experiments with platinum, in the course of which he found that the metal can be welded, and that it can be worked into foil and wire. A new process of rendering platinum malleable, by treatment with arsenic, was described by Achard in 1784. Macquer and Baumé succeeded in melting platinum in the focus of a powerful concave mirror. But in spite of all the work that was done on platinum during the latter part of the eighteenth century, it was not until the beginning of the nineteenth, and chiefly through the labors of certain Englishmen, that it yielded to metallurgical treatment and became a commercial product. In 1819 platinum was discovered in the gold placers of the Ural Mountains, and a few years later Russia became the chief source of commercial platinum.

The most important developments in the platinum industry were the perfecting, by Wollaston, of a process of making malleable platinum from the pure spongy metal, and the achievement of Deville and Debray, in 1858, of devising a process by which large quantities of the metal can be melted.

Owing to a rapidly increasing demand and a nearly stationary supply, the value of the metal has enormously increased in recent years, so that during the first decade of the present century the price of platinum has not only surpassed but more than doubled that of gold.

PLATINUM MINERALS.

In my experience as a teacher I have found that few words are so commonly misunderstood and incorrectly used as the simple term mineral. I may be pardoned, therefore, if I preface my description of the platinum minerals with a brief explanation of its meaning. In the popular sense we speak of minerals, or mineral products, to designate those materials which make up the solid crust of the earth, or which are taken out of "the bowels of the earth," in contradistinction to those which are derived from the animal and vegetable kingdoms. In the more specific sense, however, in which the term is employed in science, a mineral is a naturally occurring inorganic substance, having a definite chemical composition and definite physical characters, the essential feature being its homogeneity.

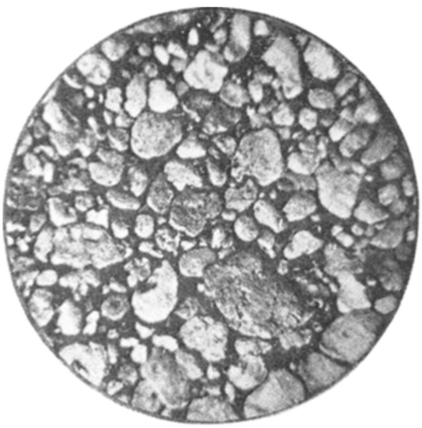
Now suppose we found such a natural substance to contain platinum and that this metal formed an essential part of its composition, we would then speak of this substance as a platinum mineral, and if it contained the metal in sufficient amount to permit of its commercial extraction, we would call it a platinum ore.

The mineralogy of platinum is extremely simple; for there are but a very few minerals that contain the metal, and only one of these constitutes an ore, and that is the *native platinum* from which the commercial metal is exclusively obtained.

But, although native platinum is not chemically combined with any other elements, it nevertheless invariably contains a number of other metals which are mixed or alloyed with the platinum. Among these must be mentioned five rare metals which are closely related to platinum, namely, iridium, rhodium, palladium, ruthenium, and osmium, as well as the more familiar ones,—iron, copper, and gold. For the reason that native platinum is always host to a number of such guests or strangers, it has also received the name of *polyxenite,* meaning many strangers.

Native platinum occurs mainly in river sands and alluvial deposits, in the forms of grains, scales, and nuggets; the grains, though usually worn and rounded (Fig. 1),* not infrequently show distinct cubical crystallization (Fig. 2). The nuggets are usually small, though masses of considerable size, weighing up to 20 pounds, have occasionally been found in different localities (Fig. 3).

FIG. 1.



Thin, worn platinum grains, Colorado River, Colombia.

FIG. 2.

Rough unworn platinum grains, Tulameen River, British Columbia.

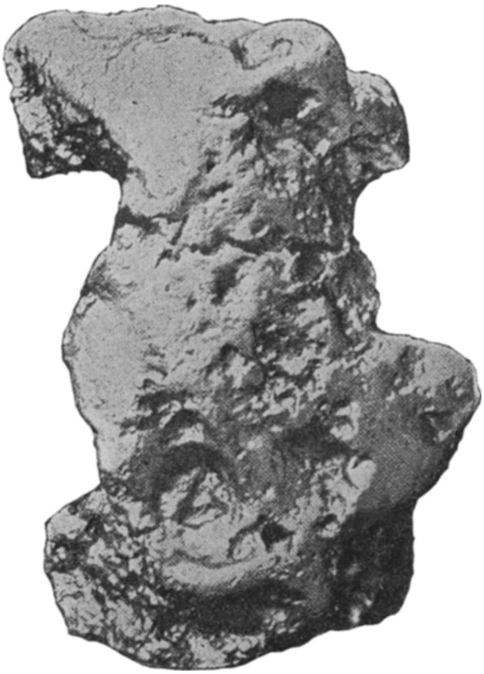
Owing to their exceptional occurrence, the larger nuggets have mostly found their way into collections of minerals.

Apropos of this, I can tell you an amusing anecdote, one of the few I have heard in connection with platinum. It is from Lewis's "Life of Goethe," and runs something like this: In the twenties of the last century a large and fine specimen of native platinum was included in a consignment from the Czar to the court of Saxe-Weimar, with the instruction that the specimen be forwarded to Doebereiner, then Professor of

* My grateful acknowledgments are due to Professor James Furman Kemp for kindly permitting me to copy this and other illustrations from his monograph on platinum and associated metals. U. S. Geological Survey Bulletin No. 193.

Chemistry at Göttingen. It was, however, first submitted to Goethe, friend and Prime Minister of the Duke, as well as an ardent collector of minerals. The poet took such a fancy to this curiosity that he quite forgot to return it or send it to its destination. Doebereiner, worried over the non-arrival of the promised treasure, wrote to Goethe, courteously inquiring as

FIG. 3.



Nugget of platinum, weighing 14 pounds, found at Nizhni Tagilsk in 1894.

to what had become of it. He received no reply either to this or to the more urgent inquiries that followed; so, as a last resort, he wrote directly to the Duke, imploring him to order Goethe to surrender the specimen. This was the reply: "Why bother the old fool? I will write to my brother-in-law, the Czar, and he will be pleased to send you another and even finer nugget."

Native platinum has a grayish-white or gray color, and strong metallic lustre. It is malleable, and harder than gold or silver. Its specific gravity varies within wide limits, say from 14 to 19, owing to the presence of iron and other metals. Some varieties are strongly magnetic, even showing polarity, while others are scarcely attracted by the magnet.

The chemical composition of native platinum from various localities is shown in the analyses given in Professor Kemp's admirable bulletin. The platinum content varies from 51.5 per cent. to 86.5 per cent., while the remainder is made up mainly of iron and the other platinum metals.

When the mineral contains very large proportions of iridium, so that the latter metal preponderates, it is called platiniridium.

FIG. 4.

Sperrylite in cubes from Vermillion Mine, Ontario.

This variety, which may contain over 75 per cent. iridium, is extremely rare. It is whiter and harder than platinum, and is the densest of all minerals, its specific gravity being nearly 23.

Small proportions of platinum are found in a few rare minerals, such as *native palladium* and *iridosmine*. The only known compound of platinum that has so far been met with in Nature is *sperrylite*, an arsenide of the metal, $PtAs_2$. It is likewise a very rare mineral, and has been found only in a few localities, notably in a copper mine near Sudbury, in the western part of Ontario (Fig. 4).

Sperrylite forms very small, shining crystals, similar to those of pyrite. It is hard and brittle, and has the specific gravity 10.6.

In addition to the true platinum minerals, some other minerals which are commonly associated with native platinum in the gravels, and often attached to the nuggets, should be mentioned here. It is through studying these associations that geologists may expect to find clues as to the original home of the metal in the mother rock. The most important of these

FIG. 5.

Platinum nugget with olivine and octahedral chromite, Tulameen district, British Columbia (after Kemp).

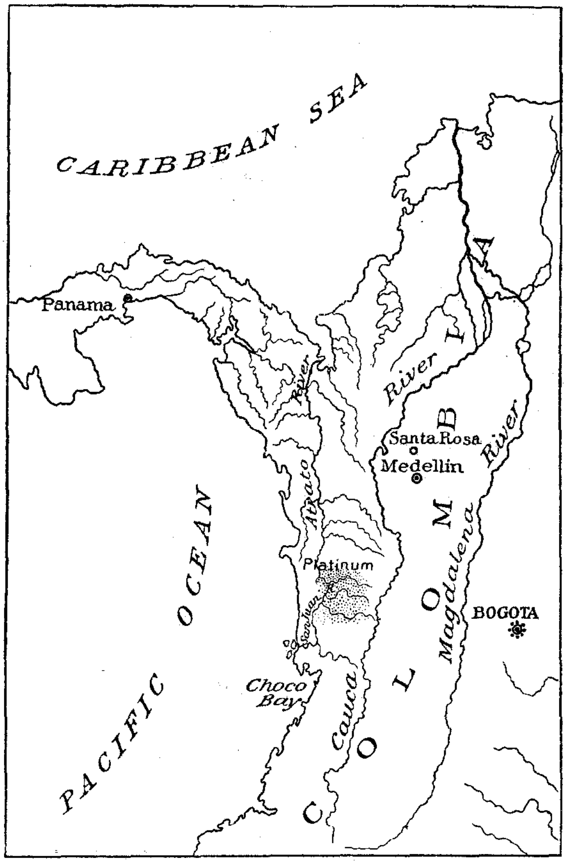
companions of platinum are chrome iron, olivine, serpentine, pyroxene, and native gold (Fig. 5).

These and a number of other dense and hard minerals which accompany the platinum are the same as those usually found in the gold-bearing gravels and sands, and must be regarded as fragments worn away from the rock in which these metals were originally deposited.

A very complete and thorough discussion of the work done can be found in Professor Kemp's bulletin on "Platinum and Associated Metals," published in 1902. According to Professor

Kemp, this has been accomplished in a few instances, but the quantities of platinum that have been found in the country rock are so small that the commercial extraction of the metal from such rocks is out of question. My own experience seems to confirm this.

FIG. 6.



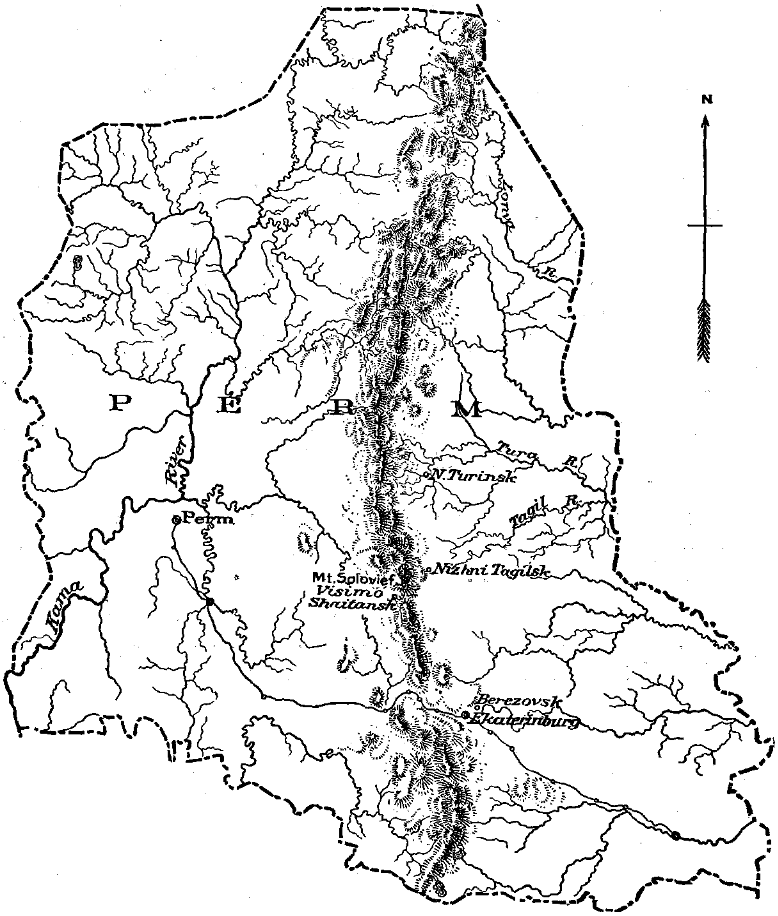
Map of Colombia.

SOURCES OF COMMERCIAL PLATINUM.

While native platinum has been reported from many and widely scattered localities, both of the Eastern and Western Hemispheres, the districts which have produced the metal in commercial quantities are few in number and limited in extent.

As I have stated before, platinum was first observed in the gold placers of Colombia. The river Pinto, from the sands of which were obtained the first specimens that were brought to Europe, is doubtless one of the tributaries of the San Juan, in

FIG. 7.



Map of the Government of Perm.

the district known as El Choco (Fig. 6). Before the discovery of platinum in the Ural Mountains, Colombia furnished the bulk of the metal of commerce, and, while its production at the present time is probably only one-twentieth that of Russia, it still occupies the second place as a platinum producer. It is estimated that Colombia has yielded over 50,000 pounds of platinum, mostly from the San Juan district.

Among the earlier finds of platinum, those made in the gold washings of the island of San Domingo, and especially the province of Minas Geraës, in Brazil, are often mentioned. It does not appear, however, that either of these localities has ever contributed appreciably to the world's supply.

It was not until 1819 that platinum was first observed in Russia. In that year small quantities of grayish-white metallic grains were gathered in the gold washings of Verk-Isetsk, in the Siberian Urals. They were not recognized as platinum until 1823. The development of the great deposits at Nizhni Tagilsk began in 1824, and in the following year the metal was found also in the Goroblagodat district.

Since that time the metal has been found in many other localities in the government of Perm (Fig. 7), but those which have produced the bulk of the commercial metal are in the districts southwest of Nizhni Tagilsk and northwest of Nizhni Turinsk. The Goroblagodat and Bisersk districts on the northeast of the latter place are at present the most active producers of the metal.

Outside of Russia and Colombia, platinum has been produced, though only in comparatively small quantities, in California, Oregon, Washington, British Columbia, Borneo, and New South Wales. Great efforts have been made in recent years to increase the output, especially in British Columbia and in New South Wales, but apparently without success.

EXTRACTION AND PURIFICATION.

Since the platinum of commerce is exclusively derived from alluvial deposits, the methods employed for its recovery are essentially similar to those employed in gold placers; indeed, if we except the Uralian districts, it may be said that platinum is generally obtained as a by-product in gold washing.

The Russian platinum-bearing gravels, which are covered with barren material, from a few feet to 50 feet in depth, are worked partly by open mining, but usually by sinking shallow shafts and drifting along the pay streak. The latter, as a rule, is only a few feet in thickness, and the gravels are said to run from .05 to 1 ounce per cubic yard.

The washing plants are mostly of a peculiar, rather primitive construction, though quite recently modern methods and apparatus have been successfully introduced on some of the properties.

(For descriptions and recent improvements in the recovery of platinum, with or without gold, see Mineral Resources, 1905–1906.)

The metal obtained by washing and various concentrating processes, and freed from gold, constitutes the crude platinum, or platinum ore, of commerce.

As we have seen, this contains various metals that render the platinum unworkable, and the ore has to undergo a refining process to convert it into the commercial form.

Many attempts to render platinum malleable and ductile were made during the latter part of the eighteenth century, and while a few men, like Achard, the Count von Sickingen, and the skilful metal workers Chabanneau and Jeannetty, of Paris, succeeded in doing it on a small scale, it was not until the early years of the nineteenth century that the platinum industry was really founded, and the creators of this industry were Englishmen.

About the year 1800 Charles Knight devised a process which, while still imperfect, embodied the principal features of the method by which all commercial platinum was obtained for more than fifty years. It consisted in dissolving the crude metal in aqua regia, precipitating the solution of the chloride with sal ammoniac, then packing the dried precipitate into conical moulds of fire clay, and strongly heating it in the mould. It is said that the metal was thus obtained as a coherent mass which could be hammered and worked into various forms.

The product, however, still lacked solidity and homogeneity, and it was only by certain important modifications and improvements that it became a commercial success. The improved process is usually credited to the chemist Wollaston, but according to Roscoe the main features were invented by a relative of a member of the firm of Johnson & Matthey. However that may be, it is certain that the improved process was first described by Wollaston in the Bakerian Lecture for 1828, and Faraday, who was undoubtedly well informed on the subject, said in a lecture on platinum, delivered in 1861, "This substance has been given to us hitherto mainly through the philosophy of Dr. Wollaston."

In the process described by Wollaston the double chloride of platinum and ammonium was very carefully heated to a temperature just high enough to expel the ammonium salt, whereby the cohering of the resulting particles of metal was prevented. The product was then rubbed by hand, sufficiently fine to pass through a lawn sieve. It was then made into a uniform pulp with water, and this was placed into a brass cylinder, where it was powerfully compressed by means of a lever. The hard cake which resulted was heated on a charcoal fire, to expel the water and promote cohesion, and finally heated at the highest temperature attainable in a wind furnace. By forging the white-hot cake under a heavy hammer, it was consolidated into an ingot, which could be beaten into thin sheets and drawn into the finest wire. The refractory natural product had been conquered, and henceforth platinum was one of the useful metals.

That platinum is not infusible was shown in 1758, when Baumé and Macquer succeeded in melting grains of the ore by the aid of a concave mirror; but the melting of considerable quantities of the metal was a feat which was first accomplished in our own city: in 1847 Robert Hare demonstrated that the difficult and tedious process of consolidating platinum sponge could be replaced by the simple operation of fusing the metal in the oxyhydrogen flame. He melted as much as two pounds of platinum at a time.

His process was greatly improved by the French chemists Deville and Debray, and it was through them that it became more generally known, and that it was adopted by the platinum refiners.

Deville's furnace consists of two well-fitting pieces of quicklime, hollowed out to form a crucible or hearth. An opening at the side serves as a spout for the molten metal and for carrying off the fumes and products of combustion. The nozzle of the oxyhydrogen blowpipe is introduced through an opening in the centre of the cover.

Lime is used because it is infusible at the temperature of the flame, and because it is porous and absorbs the slags formed during the operation. It is also a poor conductor of heat.

I had the privilege of seeing this process in operation at the Heræus works at Hanau. Although they used illuminating gas instead of hydrogen, it was amazing to see the platinum sponge and scrap melt like butter as fast as it was fed in. You cannot, however, distinguish the metal from the lime, as both glow with the same intensity, and one must also protect the eyes with dark glasses when looking into the furnace. At the Heræus works I was shown all the principal operations, from the treatment of the ore with aqua regia, to the production of the ingot. Incidentally I also learned how such by-products as iridium, palladium, rhodium, and osmic acid are obtained and handled.

Although several methods have been proposed for the refining of platinum, it appears that the treatment of the ore in the different works is essentially the same; for there is little difference in the manufactured product, whether it come from London, Paris, Hanau, St. Petersburg, or our American refineries.

At the Heræus works the ore is boiled under pressure with dilute aqua regia, whereby the platinum and some of the associated metals pass in solution in the form of chlorides, while the iridosmium and gangue remain undissolved. The chloride solution is evaporated to dryness and heated at 125° C. The residue is then dissolved in water, acidified with hydrochloric acid and precipitated with sal ammoniac. The resulting double chloride, containing only small amounts of other metals, is finally reduced in the manner which I have already described.

The refining of platinum in the dry way, as proposed by Deville and Debray, does not seem to have proved successful, except in special cases and on a smaller scale.

The preparation of chemically pure platinum, *i.e.*, a product which is entirely free from iridium, rhodium, etc., is extremely difficult and tedious, and need not be discussed here.

PROPERTIES OF PLATINUM.

To tell an audience of chemists and students of chemistry about the properties of platinum would be like carrying coals to Newcastle. Some of the physical constants of the metal, it is true, have in recent years been redetermined and revised, but the corrections which have thus been made on the older figures have had no marked influence on the applications of the manufactured product.

What interests us here are those properties, physical and chemical, to which platinum owes its unique position among the useful metals, and its manifold applications in the arts.

The characteristic color and lustre of the metal, though long familiar to the chemist, have only in recent years caught the popular fancy, and their noble ornamental effects are just beginning to be appreciated. The specific gravity of pure platinum is 21.48, but that of the manufactured metal varies considerably, according to the manner in which it has been obtained, and is affected also by the impurities which are present in it. Pure platinum is quite soft, flexible, and extremely malleable and ductile. Like wrought iron, it can be welded at a white heat. Its coefficient of expansion is the same as that of certain kinds of glass. Its melting point is somewhat above 1700° C. (or about 3100° F.), and at still higher temperatures it volatilizes. Moissan has shown that it can be distilled in the electric furnace.

At a red heat it is markedly pervious to hydrogen gas, which is due to the fact that it combines with or absorbs this gas at high temperatures. It forms fusible alloys with many of the metals.

One of its most valuable properties is that it does not tarnish or combine with oxygen, even at high temperatures. In the molten state it does absorb some oxygen, which, however, escapes when the metal solidifies.

As many of us know from sad experience, platinum is readily attacked at higher temperatures by sulphur, phosphorus, arsenic, and silicon, and, under certain conditions, also by carbon.

You also know that platinum is practically proof against the attacks of all acids, except the mixture of hydrochloric and nitric acids. It is, however, dissolved by nitric acid when alloyed with large amounts of silver.

It is also slowly attacked by fused pyrosulphates, and more rapidly by fused nitrates and caustic alkalies.

In the finely divided states of platinum black and sponge, and even as fine wire and thin foil, it produces many remarkable chemical effects, acting as a catalytic agent, especially in the oxidation of many gases and vapors.

Colloidal solutions of platinum have been obtained in a number of ways.

USES OF PLATINUM.

Platinum has not inaptly been called "white gold." Its physical and chemical properties closely resemble those of the yellow metal with which it is generally associated in Nature. But in addition to the many virtues which it shares with gold, platinum has several most valuable properties of its own, and it is chiefly to these that it owes its many uses in science and in the arts.

On account of the great difficulties which had to be overcome in freeing platinum from the other metals with which it occurs in Nature, it was many years after the discovery of the metal before it found any practical applications. The first platinum crucible is said to have been made by Achard. It must have been a very crude affair. The German chemist's process of rendering platinum malleable was improved by the Paris goldsmith Jeannetty, who enjoyed a great reputation for the platinum goods he turned out. I suppose the prototypes of the meter and kilogram were made by his process.

At the beginning of the nineteenth century vessels made of platinum were still so scarce and costly that very few chemists could boast of possessing such apparatus. It was not until the London firm of Johnson & Matthey and the chemist Wollaston developed their method of rendering platinum workable that wire, foil, crucibles, and other articles made of the metal came into more general use. As early as 1809 Johnson & Matthey manufactured a platinum still for the concentration of sulphuric acid which weighed 424 ounces.

It would be difficult to overestimate the effects which the use of platinum apparatus has had on the progress of the sciences and arts. Writing in 1844 Liebig thus characterized the part which platinum plays in the chemist's workshop: "Without platinum it would be quite impossible to carry out a mineral analysis. To render the sample soluble, it must first be fused with suitable reagents. Glass and porcelain, or any other nonmetallic substance of which crucibles are made, would be rapidly destroyed in this operation, while crucibles made of gold or silver would melt at the high temperatures at which the fusions are made. Platinum is cheaper than gold, harder and more resistant than silver, and infusible at the highest temperatures of our furnaces; it combines the valuable properties of gold with those of porcelain. Without the use of platinum the composition of most of the mineral species would still be unknown."

That platinum crucibles were freely used in Liebig's famous laboratory is reflected by a little incident which is told by one of the biographers of the great chemist. It happened that a Paris manufacturer of platinum-ware stopped off at Giessen and visited the laboratory. On being asked whether he wished to see the Director, Professor Liebig, he replied: "M. Liebig? Who is he? I have never heard this name. Show me the way to the excellent M. Aubel. I have sold him many crucibles." Aubel was the *Diener,* or factotum, who had charge of the supplies.

But since the days when there was only one great teaching laboratory in the world, wonderful strides have been made in chemical experimentation and analysis, and the demand for platinum apparatus has grown enormously. In addition to the myriads of crucibles, of various shapes and sizes, chemists now require a host of other platinum utensils, such as dishes and trays, spatulas, tubes, distilling apparatus, electrodes, etc.

As some conspicuous instances of successful experimentation which depended on the use of platinum apparatus, I may mention Moissan's great work on the isolation of fluorine and the proof by Mme. Curie and Mlle. Gleditsch, that the action of radium emanation on copper solutions does not produce any lithium, as Ramsay had supposed.

While platinum is less in evidence in the equipment of physical laboratories, it enters into the construction of a great number of apparatuses and instruments which are employed in the study of heat, electricity, spectroscopy, and the recently-discovered radiations. Much of this apparatus is made of glass, and in providing it with attachments of platinum wire and plates advantage is taken of the fact that platinum and glass expand and contract at the same rate. The coefficient of expansion of platinum is also utilized in the Breguet thermometer.

The application of platinum in the arts is extremely varied, and would be even far more extended, if it were not for the high price and the limited supply of the metal.

The nozzles of the oxyhydrogen and the oxyacetylene blowpipes which are used for cutting iron and steel, as well as for fusing platinum, quartz, and other highly refractory materials, are often made of platinum.

In the manufacture of sulphuric acid, both by the leaden chamber and the contact processes, the metal is used in very large quantities. Since Johnson & Matthey constructed their first platinum still in 1809, this old firm and other manufacturers have furnished a great number of such retorts, and of much greater capacity, to sulphuric acid works in all parts of the world. In the newer contact process, as well as in other chemical manufactures which depend on catalytic action, platinum sponge or platinized asbestos are largely used as the "contact materials." Enormous quantities of platinum also are consumed in the manufacture of electrical appliances, especially of incandescent lamps and the sparking points for internal combustion engines.

But, impressive as are the quantities of platinum required for the purposes I have mentioned, they are equalled, if not exceeded, by those which are absorbed in the manufacture of dental supplies. It is estimated that fully 50 per cent. of the platinum of commerce is consumed in the production of pins, sockets, and other attachments of artificial teeth.

Passing over some minor uses of platinum, as in the construction of standards, the manufacture of surgical instruments, electroplating, china painting, pyrography, etc., it still remains for me to call your attention to another application, which, while not entirely new, has only recently assumed very considerable proportions. I refer to its use in jewelry. For many years parts of jewelry—for instance, of chains, rings, and scarf-pins, etc.—have been made of platinum, on account of the pleasing contrast of its color with the various shades of gold; but it is only in recent years that the beauty of the metal has come to be fully appreciated. At the present time the greater part of the more elaborate settings of diamonds and pearls, as well as a great number of other articles of jewelry, are made of this metal.

A question that naturally suggests itself here is as to whether so precious and noble a metal as platinum is not available for coinage. Aside from its great intrinsic value, its fine and permanent lustre, and its high specific gravity, it readily takes the impression of the die and is harder and tougher than gold and silver. It is probable that in the early years of its discovery in Colombia considerable quantities of platinum passed into the Spanish coin-gold; while later the Spanish Government is said to have issued an order directing its officials to dispose of the objectionable companion of gold by casting it into the sea; and still later the King decreed that the entire output of platinum be delivered to the Crown. It is believed that much of this platinum was used to debase the Spanish coinage.

In 1828, when the Russian Government had accumulated enormous stores of platinum from the Uralian districts, it was decided to convert this surplus into coins, and accordingly three denominations—of 3, 6, and 12 rubles—were minted and put in circulation. This minting of platinum continued until 1845, when it was stopped and the coins were withdrawn from circulation. The reason for this was that, the Russian Government being unable to fix and maintain the price of the metal, large quantities of the coins passed into other countries. Many of them are still preserved in the collections of numismatists. Those shown on the screen are in the collection of the United States Mint in this city; others can be seen in the loan collection in Memorial Hall.[2]

The metal from which these coins were made was not pure platinum. According to Faraday, it contains platinum, 97.0; iridium, 1.2; rhodium, .5; palladium, .25; together with traces of copper and iron.

Just as gold and silver are alloyed with copper (and other metals) to increase their hardness and wearing qualities, so platinum is often alloyed with iridium to increase its resistance to abrasion and the attack of chemicals. Such an alloy goes under the name of "hard" platinum, as distinguished from ordinary platinum. It is more expensive than the latter. Thus most of the vessels used by chemists contain about 2 per cent. of iridium, while much larger proportions of the latter—from 10 to 15 per cent.—are added to the platinum used for the construction of standards of length and weight, for electrodes exposed to severe chemical attack, for sparking plugs, and the points of fountain pens.

For special purposes platinum is sometimes alloyed with

[2] I am indebted to the kindness of Dr. Jacob B. Eckfeldt, Chief Assayer of the Philadelphia Mint, for obtaining permission to photograph these coins.

other metals. An alloy with rhodium is used in certain electric pyrometers; and various alloys with copper, nickel, tungsten, and manganese serve as substitutes for steel in the construction of non-magnetic watches.

Of the compounds of platinum, only a few have found application in analytical chemistry, photography, and physics.

The most important, platinum chloride, or rather chloroplatinic acid, is an invaluable reagent; and barium platinocyanide is used on account of its fluorescence, which converts the ultra-violet rays and X-rays into visible radiations. The shadows made by X-rays are best projected on screens coated with this salt.

SUBSTITUTES FOR PLATINUM.

In view of the great increase in the price of platinum it is but natural that many and persistent attempts have been made to find substitutes for it. In a few instances this has been partially, or even wholly, accomplished; as yet, however, the introduction of such substitutes has had no appreciable effect upon the price of the metal; indeed, it may be said that the demand for platinum has steadily increased in spite of them.

Among the substitutes may be mentioned platinum-clad nickel steel wire, which is beginning to displace the solid wire in incandescent electric lamps; wires of nickel alloys which are used in making the cheaper grades of artificial teeth; asbestos threads which have replaced platinum wire in the Welsbach mantles; and the fused-quartz ware, now so extensively employed in chemical laboratories in the place of platinum utensils.

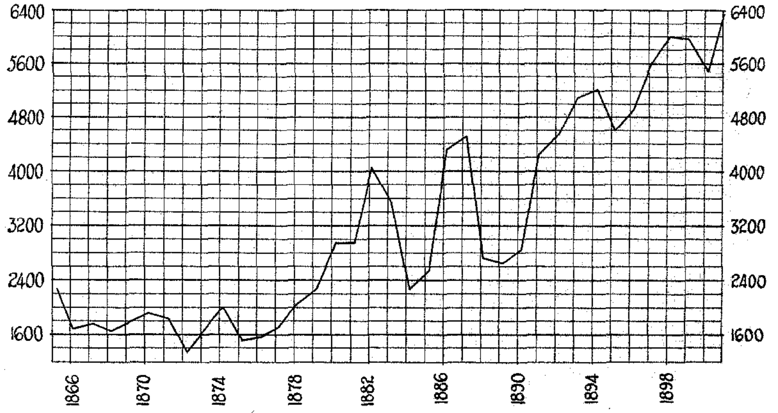
Perchloric acid and sodium cobaltic nitrite are useful in saving platinic chloride in the laboratory.

PRODUCTION.

Statistics on the production of platinum, from the time when it first appeared on the market up to the present, may be found in many publications. An excellent *résumé* up to the year 1901 is given by Dr. B. Neumann in his work "Die Metalle." Our time does not permit of a full discussion of this subject, and I shall content myself, therefore, with a few quotations from this work and some more recent reports, chiefly those published in the "Mineral Resources of the United States."

It is estimated that up to 1778 the entire output of Colombia amounted to 1,943 kilograms; that is, about two tons of the metal. According to Humboldt, the annual production at the time when platinum was discovered in Russia was 545 kilograms. After that the Colombian production gradually decreased. Neumann estimates that up to 1900 Colombia had yielded from 16,000 to 20,000 kilograms. In 1906 the platinum exported from Colombia was 6,813.38 troy ounces (about 200 kilograms).

CHART I.



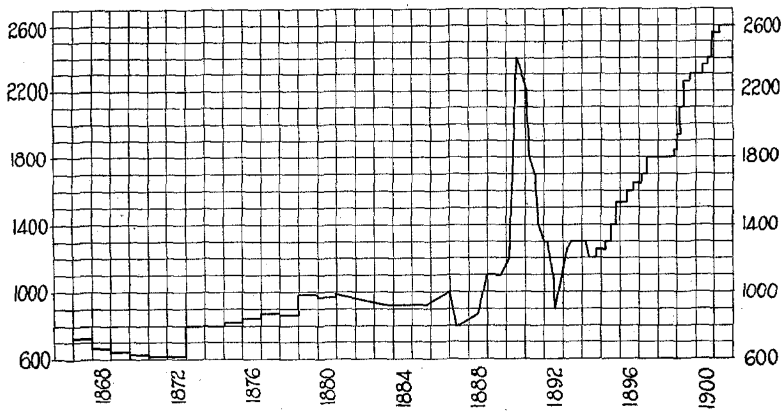
Russian production of platinum, in kilograms, 1865–1901 (after Neumann).

The production of platinum in the Uralian districts began in 1824. From that year until 1845, when the coinage of platinum stopped, it amounted to 30,381 kilograms, of which Nizhni Tagilsk furnished 29,542 kilograms. From that time up to 1864 about 12,000 kilograms were mined in the Urals, and the graphic representation on the screen, borrowed from Neumann, shows the fluctuations of the annual output of Russia, since 1866. It indicates a fairly steady increase since 1875. During the last few years it has been approximately 6,500 kilograms, or somewhat above 200,000 ounces. It should be stated here that the official figures are probably 20 to 25 per cent. below the actual production, owing to the well-known fact that much of the metal is stolen at the mines.

In the United States the production of platinum has been very irregular; it now amounts to several hundred ounces a year: in 1906 a high record was reached with 1,439 ounces, valued at $45,189. Statistics of the production of platinum in British Columbia, Borneo, and New South Wales show great fluctuations, but the totals are quite small, and have probably not reached 100 kilograms in any one year.

The distribution of platinum in the principal industries was estimated by Siebert (writing in 1902) to be as follows: 50 per cent. for dental manufactures; 30 per cent. for chemical

CHART II.



Price of platinum, per kilogram, in marks, 1867–1901 (after Neumann).

and electrochemical industries, and 20 per cent. for electrical manufactures and jewelry. The use of platinum for jewelry has greatly increased since 1902.

THE VALUE OF PLATINUM.

During the three or four decades which followed the discovery of platinum in Colombia the valuable properties of the new metal remained unrecognized, and it was then regarded as an undesirable companion of gold. As late as 1778 the Spanish Government ordered all platinum to be sent to the royal treasury, without any compensation. Subsequently, the munificent reward of two dollars per pound was paid by the Crown, but the miners found it more profitable to sell it to English traders, who paid

$12 per pound and then sold it at a much higher price in Europe. Humboldt states that in 1819 the price of the metal on the spot was $8 a pound, while it sold in Paris for nearly four times that amount.

The first platinum found in Russia was sold for $3 a pound. In 1825 the lessee of the Nizhni Tagilsk placers paid $3.50 to $7 a pound, and sold it at $14 to the Imperial Mint.

In 1867 the firm of Johnson, Matthey & Co. paid more than $25 per pound for the crude metal, and in 1877 the price had risen to nearly $40. Our diagram, which is also borrowed from Neumann, shows the fluctuations in the price of platinum, per kilogram, in marks. Dividing the latter by 8, we have roughly the price per pound in dollars.

In 1902 platinum ingots were quoted at $18 per troy ounce; in January, 1906, at $20.50 (about the price of gold, $20.672) per ounce; and during the following months the price gradually advanced to $38 per ounce. While ordinary or soft platinum remained at this figure for some time, hard platinum, containing much iridium, rose to $41 in February, 1907. The prices then declined somewhat, only to rise again, until, at present, ingot platinum is quoted at $45.50.

It may interest you to know how the price of chemical platinum-ware has advanced during the past ten years. The following figures were furnished to me by Messrs. J. Bishop & Co., of Malvern, Pa., through the courtesy of Mr. Geo. D. Feidt:

	1902.	1912.
Crucibles, per gram........	$ .75	$1.70
Foil	.60 to .70	1.55 to 1.65
Wire	.60	1.50
Gauze	.95	1.95
Sponge	.60	1.50

In thus concluding my lecture on platinum I am well aware that I have only lightly touched upon the chemistry and other scientific aspects of the subject. My main object was to show the causes which have operated in advancing the once-despised by-product of the gold placers to the rank of the most precious of the useful metals.